Parameterization of Near-Surface Refractivity Profiles Over the Ocean and their Effects on IR/Rf Propagation

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LONG-TERM GOALS

The long-term goal of the Naval Postgraduate School's research effort is to improve parameterizations and operational models that describe atmospheric and surface wave effects on radar and optical sensor/weapons systems, which will ultimately benefit U.S. Navy warfighters in planning and executing operations by improving sensor performance and target detection predictions and sensor optimization for the current environment.

OBJECTIVES

The overall scientific objective of the proposed research effort is to develop and validate a comprehensive model to describe air-sea fluxes and near-surface atmospheric profiles above ocean waves in terms of readily measured or modeled mean atmospheric and ocean surface characteristics. This objective is scientifically and operationally important and timely, due to its direct impact on naval sensor and weapons system performance and Homeland Security issues, such as port security and special warfare operations. Specific objectives and expected short and long-term payoffs to the Navy are:

1) Verification and improvement of Monin-Obukhov flux-profile relationships over ocean waves, which leads directly to improvements in: a) Rf and IR propagation and sensor performance predictions; b) vertical particulate and gaseous concentration parameterizations for Chem/Bio warfare applications; and c) coupled ocean-atmosphere meso-scale models.
2) Verification and improvement of the NPS evaporation duct model within AREPS for predicting radar-wave propagation over a wide spectrum of frequencies and atmospheric and wave conditions. This objective is important to provide accurate propagation predictions for naval sensor performance optimization and tactical decision-making.
3) Verification and improvement of the NPS optical turbulence and refractivity model. This is important for application in IR propagation TDAs, such as EOSTAR and IRBLEM.
4) Incorporate atmospheric and surface wave effects into the determination of small combatant craft radar and infrared signatures, using the NPS evaporation duct model with AREPS.
5) Evaluation of using COAMPS-predicted METOC data as inputs to the NPS model and AREPS to make propagation loss and target detection predictions. If COAMPS proves to be successful in this application it would represent an important tool for Navy warfighters to plan and execute a wide variety of missions.

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These objectives represent a continuation of our research efforts, which directly support achieving the above stated requirements and focus on transitioning recent research results and scientific advances to near-term naval applications. In addition, the critical areas of special operations and Homeland security, which are of paramount importance since 9/11, will be supported by the effort, through improved assessment of the detectability of Naval Special Warfare (NSW) units and terrorist infiltrators by optical, IR and radar sensors. In this regard, we have taken on supporting NSW platform EM/IR detectability tests by the ship signature directorate of the Naval Surface Warfare Center-Carderock Division (NSWC-CD), and we are also formulating integrated models for Force Protection for SPAWAR (PMW-155).

APPROACH

The approaches used to meet the objectives of this research effort outlined above are as follows (where the numbered items here correspond to the like-numbered items above):

1) Perform examinations of near-surface mean meteorology, turbulence and wave data obtained on the NPS flux buoy during the RED experiment in conjunction with kite profiles of temperature and humidity obtained on the R/V Wailoa to evaluate flux-profile relationships and the possible influences of ocean waves on these empirical functions.
2) Compare radar-wave propagation predictions produced by using mean METOC data from the NPS flux buoy with the NPS evaporation duct model and AREPS with actual microwave propagation measurements obtained during the Wallops ’00 and RED ’01 experiments to validate the combined NPS evaporation duct and Advanced Propagation Model’s over a wide variety of environmental conditions and radar system attributes. This work is being carried out in collaboration with Janet Stapleton (NSWC-DD) and Kenn Anderson (SSC-SD)
3) Evaluate IR propagation models using NPS flux buoy data from the RED experiment and actual IR transmission measurements obtained by SSC-SD (Stephen Doss-Hammel).
4) Mean meteorological data obtained from small boats were used as inputs to the NPS/APM models to compute propagation loss for the Dam Neck and SCI radar signature tests. Comparisons between model predictions and actual detection data obtained by NSWC-CD were used to determine atmospheric effects on radar signature. This work is being performed in collaboration with John Young (NSWC-SD).
5) Compare COAMPS-derived radar propagation predictions with in situ predictions and actual radar measurements off Dam Neck, VA and Oahu, HI, to evaluate the value of COAMPS forecast data in predicting radar performance. NRL-MRY (Steve Burke) conducted special runs for the RED experiment off Oahu for this effort. Operational COAMPS data were used for the Dam Neck, VA case.

WORK COMPLETED

Tasks called for in all the approaches outlined above have been completed during FY 03. Work on some objectives will continue into FY 04. Data collected during the RED experiment and propagation tests off San Clemente Island and Dam Neck, VA, were analyzed and interpreted for the projects worked on during FY 03. Processed data from these experiments and in some cases extensive data reports have been sent to collaborating scientists and agencies and to sponsors. The numbered items listed below list specific tasks completed, and correspond to the numbered items in the above paragraphs:

1) Interpretations of flux-buoy profiles using buoy and kite profile data from the RED experiment have been completed and the results were included in two presentations and papers, one by Davidson et al. and the other by Frederickson et al., at the AMS conference in February 2003 (see publications section below).
2) Propagation predictions produced by the NPS evaporation duct model and AREPS have been evaluated with actual microwave propagation measurements. Results were presented in two conference papers given by Frederickson et al. A comprehensive paper by Frederickson and Davidson describing and evaluating the NPS evaporation duct model has been submitted to the *Journal of Applied Meteorology*. A master's thesis by A. Moys (LCDR, RN) also presented results from Wallops '00. Work on this objective continues into FY 04.
3) Evaluations of IR propagation using NPS flux buoy data from the RED experiment were performed and were presented in papers by Doss-Hammel and Tsintikidis at the AMS meeting in February 2003 (see publications).
4) Mean meteorological data obtained from small boats were successfully used to determine atmospheric effects on radar signature determination for tests at Dam Neck, VA and off San Clemente Island. Results were presented in a master's thesis by David Kuehn (LT, USN) and in a paper by Davidson et al. at the BACIMO meeting in September 2003.
5) COAMPS-derived radar propagation predictions were successfully evaluated for cases off Dam Neck, VA and Oahu, HI, and results are presented in theses by Adam Newton and David Kuehn and by a paper by Davidson et al. to the IEEE/URSI meeting in Columbus, OH, in June 2003. Special COAMPS runs for the Wallops '00 experiment will be performed in FY04 and evaluations will be performed in collaboration with NRL-MRY (S. Burke).

RESULTS

Results pertaining to the specific objectives listed above are as follows:

1) It was found that the near-surface profiles of temperature and humidity (and hence modified refractivity) measured on the NPS buoy and from the kite-sondes often disagreed with predictions based on traditional Monin-Obukhov similarity theory. These scalar gradients tended to be less steep just above the surface in most cases, indicating that ocean waves induce significant mixing in the lower part of the surface layer, which decreases the scalar gradients from predictions based on the traditional 'Kansas'-type functions that were determined over land. These wave-induced influences on the modified refractivity profile appear to contribute to the observed discrepancy between measured microwave propagation loss and APM-predicted loss based on the mean NPS buoy data, especially in X- and Ku-band, which exhibit much lower loss than predicted.
2) It has been determined from an evaluation of Wallops '00 and RED '01 data that using the NPS evaporation duct model with modern propagation codes, such as APM, produces very high quality propagation predictions in unstable conditions, usually to within 2 dB for ranges within and just beyond the radar horizon. In stable conditions the accuracy of the propagation predictions exhibits more scatter than in unstable conditions. For very low wind speed stable cases the model results become suspect, because the model is very sensitive to the input parameters.
3) Results on evaluating IR propagation models from data obtained during the RED Experiment have so far not been promising due to unexplained high noise levels in the IR propagation data. NPS has been informally assisting in evaluating the EOSTAR optical tactical decision aid, based on experience from class exercises employing the model.
4) The use of onboard METOC measurements with the NPS evaporation duct model and APM to determine atmospheric effects on radar signatures and the detectability of small combatant craft has

been conclusively demonstrated. Very high correlations were observed between modeled propagation loss and actual detection measurements for a small craft in a coastal region during tests conducted off Dam Neck, VA. Radar detection of small combatant craft with low radar cross sections can be successfully predicted in a coastal region using the NPS evaporation duct model and AREPS. Atmospheric data must be considered in order to accurately determine the radar cross section of platforms from field tests.
5) From tests off Dam Neck and Oahu it was demonstrated that COAMPS-derived predictions of radar propagation characteristics were very useful for forecasting propagation changes from day to day, but could not accurately forecast diurnal variations with a time scale of several hours in a complex coastal region.

IMPACT/APPLICATIONS

The results obtained from the research efforts conducted in FY 03 have improved our knowledge of ocean wave effects on near-surface atmospheric properties, which in turn will lead to an improved ability to predict IR and microwave propagation. Our best accomplishment was to validate the NPS physical models that describe the atmospheric refractivity conditions for radar-wave and infrared propagation, not only with in-situ meteorological turbulence and profile data, but most importantly with actual propagation measurements from at-sea experiments and tests, in order to improve and validate the models for transition to operational use.

TRANSITIONS

The Naval Postgraduate School's evaporation duct model has been incorporated into the latest versions of the Advanced Refractive Effects Prediction System (AREPS) tactical decision aid as a user-selected option. AREPS is currently in wide use throughout the Fleet to predict radar performance and target detection capabilities for operational decision-making and sensor optimization purposes. Propagation predictions from the NPS model and APM are being used to help determine radar signatures of small combatant craft by NSWC-CD.

RELATED PROJECTS

This research effort is closely related to other projects being conducted by NPS in the field of atmospheric effects on Rf/EO propagation. NPS has been and continues to be a participant in propagation studies conducted by the Naval Surface Warfare Center, Dahlgren Division off Wallops Island ('98, '00 and proposed for '05), and radar signature studies conducted by NSWC, Carderrock Division off Dam Neck, Virginia, in '02, with additional tests planned. We are currently working jointly with SPAWAR (PMW-155) on the development of an integrated model for Rf propagation.

PUBLICATIONS

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